

## 8. ACCOUNTING FOR EMISSION REDUCTIONS

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Earlier chapters of this report examined GHG emissions from each of five waste management options. This chapter recapitulates the emission factors for each option, explains the analytic framework for applying emission factors, and reviews opportunities for GHG emission reductions.

In the discussion that follows, we focus on national average conditions. For example, we represent landfills as having the national average landfill gas recovery systems, and we represent combustors based on mass burn units with the national average system efficiency for collection of ferrous metal. As shown in the previous chapters, GHG emissions are sensitive to many variables, including several that are site-specific. At specific locations, the GHG emission factors can differ from those described below. To allow for customizing of emission factors to better reflect local conditions, EPA has developed a spreadsheet accounting tool, the Waste Reduction Model (WARM), which enables users to input several key variables (e.g., information on landfill gas collection systems, electric utility fuel mix, transportation distances).<sup>1</sup> We encourage readers to take advantage of this model when assessing their waste management options.

### 8.1 NET GHG EMISSIONS FOR EACH WASTE MANAGEMENT OPTION

This section presents the net life-cycle GHG emissions for each waste management option for each material considered. These emissions are shown in 12 exhibits that summarize the GHG emissions and sinks in MTCE/ton and MTCO<sub>2</sub>E/ton, which are described in detail in earlier chapters. In these exhibits, emission factors are shown for mixed plastics, mixed recyclables, and mixed organics. We developed the emission factor for mixed recyclables by calculating the average (weighted by tons recycled in 2000) of emission factors for aluminum cans, steel cans, HDPE, LDPE, PET, corrugated cardboard, magazines/third-class mail, newspaper, office paper, phonebooks textbooks, and wood products. The emission factor for mixed plastics is the average (weighted by tons recycled in 2000) of emission factors for HDPE, LDPE, and PET. The mixed organics emission factor is the average (weighted by tons composted in 2000) of emission factors for yard trimmings and food discards.<sup>2</sup>

As mentioned in Chapter 1, we used a waste generation reference point for measuring GHG emissions; i.e., we begin accounting for GHG emissions at the point of waste generation. All subsequent emissions and sinks from waste management practices then are counted. Changes in emissions and sinks from raw material acquisition and manufacturing processes are captured to the extent that certain waste management practices (i.e., source reduction and recycling) affect these processes (for reference, GHG emissions from raw materials acquisition and manufacturing are shown in the first column of several exhibits in this chapter). Negative emission factors indicate that from the point of waste generation, some MSW management options can reduce GHG emissions.

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<sup>1</sup> Microsoft Excel® and Web-based versions of this tool are available online at the following Web site: <http://www.epa.gov/globalwarming/actions/waste/tools.html>.

<sup>2</sup> All data on recycling and compost rates are from U.S. EPA Office of Solid Waste. 2002. *Municipal Solid Waste in the United States: 2000 Facts and Figures*, EPA 530-R-02-001.

Exhibits 8-1 and 8-2 show the life-cycle GHG reductions associated with source reduction, presented in MTCE/ton and MTCO<sub>2</sub>E/ton, respectively. In brief, the exhibits show that, for all of the manufactured materials evaluated, source reduction results in GHG emission reductions. On a per-ton basis, aluminum cans and several paper grades have the greatest potential for emission reduction, due primarily to reductions in energy use in the raw material acquisition and manufacturing step and (for paper) forest carbon sequestration.

Exhibits 8-3 and 8-4 show the life-cycle GHG emissions associated with recycling in MTCE/ton and MTCO<sub>2</sub>E/ton, respectively. The third through fifth columns in the exhibits show the GHG reductions associated with using recycled inputs in place of virgin inputs when the material is remanufactured. As the final column indicates, recycling results in negative emissions (measured from the point of waste generation) for all the materials considered in this analysis. Emission reductions associated with recycling are due to several factors, including avoided waste management emissions and reduced process energy emissions.<sup>3</sup> In addition, emission reductions from recycling paper products (when measured at the point of waste generation) are due in part to the forest carbon sequestration benefits of recycling paper.

Exhibits 8-5 and 8-6 present the life-cycle GHG emissions from composting food discards, yard trimmings, and mixed organics in MTCE/ton and MTCO<sub>2</sub>E/ton, respectively. The exhibits show that composting these materials results in net emissions of -0.05 MTCE/ton, or -0.20 MTCO<sub>2</sub>E/ton, based on the difference between the emissions associated with transporting the materials to the composting facility and the soil carbon sequestration benefits.

Exhibits 8-7 and 8-8 present the life-cycle GHG emissions from combusting each of the materials considered in MTCE/ton and MTCO<sub>2</sub>E/ton, respectively. These exhibits show emissions for mass burn facilities with the national average rate of ferrous recovery. Results for RDF facilities are similar. As the exhibits show, mixed MSW combustion has net emissions of -0.04 MTCE/ton, or -0.16 MTCO<sub>2</sub>E/ton. Net GHG emissions are positive for plastics, aluminum, and glass, and negative for the other materials.

GHG emissions from landfilling each of the materials in MTCE/ton are shown in Exhibit 8-9. Exhibit 8-10 presents these values in MTCO<sub>2</sub>E/ton. The values in the final columns indicate that net GHG emissions from landfilling mixed MSW, under national average conditions in 2000, are positive. Among individual materials, emissions are lowest for newspaper, phonebooks, magazines/third-class mail, wood products, and yard trimmings, and highest for office paper, textbooks, and food discards.

As discussed in Chapter 7 and shown in Exhibit 7-6, the results for landfills are very sensitive to site-specific factors. Landfill gas collection practices significantly influence the net GHG emissions from landfilling the organic materials. For mixed MSW, net emissions are 0.17 MTCE/ton in landfills without landfill gas collection, and -0.06 MTCE/ton in landfills with landfill gas collection and energy recovery. The largest differences attributable to landfill gas recovery are for office paper and textbooks (both have a range of approximately 1 MTCE/ton), corrugated cardboard, and mixed paper. The CH<sub>4</sub> oxidation rate and gas collection system efficiency also have a strong influence on the estimated net emissions for mixed waste and the organic materials.

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<sup>3</sup> Process energy emissions for recycled corrugated cardboard, office paper, wood products (i.e., dimensional lumber and medium-density fiberboard), and mixed paper (broad and residential definitions) are actually higher than those for virgin production because production with recycled inputs tends to use fossil fuel-derived energy, while production with virgin inputs uses higher proportions of biomass fuel (CO<sub>2</sub> from such fuel is not counted in GHG inventories). In the case of dimensional lumber, production with recycled inputs requires more energy than virgin production.

Exhibits 8-11 and 8-12 display the national average emissions for each management option and each material in MTCE/ton and MTCO<sub>2</sub>E/ton, respectively. When reviewing the emission factors, it is important to recall caveats that appear throughout this report. In particular, these estimates do not reflect site-specific variability, and they are not intended to compare one material to another. Rather, these estimates are designed to support accounting for GHG emissions and sinks from waste management practices. A brief recap of how to apply the emission factors appears in the following section.

## 8.2 APPLYING EMISSION FACTORS

The net GHG emission estimates presented in Exhibits 8-1 through 8-10 (and the more detailed estimates in the preceding chapters) provide emission factors that may be used by organizations interested in quantifying and voluntarily reporting emissions reductions associated with waste management practices. In conjunction with the U.S. Department of Energy (DOE), EPA has used these estimates as the basis for developing guidance for voluntary reporting of GHG reductions, as authorized by Congress in Section 1605(b) of the Energy Policy Act of 1992. Other applications have included evaluating the progress of voluntary programs aimed at source reduction and recycling, such as EPA's WasteWise and Pay-as-You-Throw programs.

EPA has also assisted the Climate Neutral Network by using the methods and data described in this report to develop company-specific GHG "footprints." As part of the program, companies develop GHG footprints, which include "downstream" waste management activities, for their specific product lines or facilities. These footprints then are used to determine the reductions or offsets that are necessary to become GHG-neutral. Companies may use changes in waste management practices as part of their offset portfolio.

Additionally, EPA worked with the International Council for Local Environmental Initiatives (ICLEI) to incorporate GHG emission factors into its municipal GHG accounting software. Currently, 350 communities participate in ICLEI's Cities for Climate Protection Campaign, which helps cities and towns establish a GHG emissions reduction target and implement a comprehensive local action plan designed to achieve that target. The program has resulted in 7.5 million metric tons of annual GHG emissions reductions.

In order to apply the emission factors presented in this report, one must first establish two scenarios: (1) a baseline scenario that represents current management practices (e.g., disposing 10 tons per year of office paper in a landfill with national average characteristics in terms of LFG collection); and (2) an alternative scenario that represents the alternative management practice (e.g., recycling the same 10 tons of office paper).<sup>4</sup> The emission factors developed in this report then can be used to calculate emissions under both the baseline and the alternative management practices. Once emissions for the two scenarios have been determined, the next step is to calculate the difference between the alternative scenario and the baseline scenario. The result represents the GHG emission reductions or increases attributable to the alternative waste management practice.

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<sup>4</sup> The emission factors are expressed in terms of GHG emissions per ton of material managed. In the case of recycling, we define 1 ton of material managed as 1 ton *collected* for recycling. As discussed in Chapter 4, the emission factors can be adjusted to calculate GHG emissions in terms of tons of recycled materials *as marketed* (reflecting losses in collection and sorting processes), or changes in the *recycled content* of products.

### **Applying Emission Factors: Non-linear Relationship between Recycling and Emission Reductions and Forest Carbon Leakage**

Two caveats should be considered when applying the emission factors to analyze large-scale shifts in waste management. First, increased recycling and GHG emission reductions may have a non-linear relationship, such that emission reductions increase at a *declining rate* as recycling increases. This decline may be due to three factors: (1) energy use in manufacturing processes may be non-linear with respect to recycled content; (2) manufacturing capacity for recycled materials may be limited in the short term, so that large-scale increases in recycling would require additional capital investment in capacity; and (3) market penetration of recyclables may have limits (e.g., due to performance characteristics), such that recyclables cannot completely replace virgin inputs in the short term.

In terms of the second caveat, the forest carbon sequestration benefits of paper and wood source reduction and recycling are based on the assumption that reduced demand for a given paper or wood product translates directly into reduced tree harvesting. Given that pulpwood and roundwood can be used for many products, some of the forest carbon sequestration benefits may be lost by an increase in harvests for these other products. This phenomenon is a form of what is sometimes termed “leakage” in the context of GHG mitigation projects.

Although both of these issues are important considerations in applying the emission factors in this report, we note that the emission factors are primarily designed for use by local waste managers. The factors are intended to assess the GHG impacts of waste management decisions at a small-to-moderate scale. Readers should be cautious when applying the emission factors at a larger scale, however, since the non-linear nature of the factors and the issue of leakage become most relevant in the larger context.

Exhibits 8-13 and 8-14 illustrate the results of this procedure in a scenario where the baseline management scenario is disposal in a landfill with national average conditions (i.e., the weighted average in terms of landfill gas recovery practice). Alternative scenarios involve source reduction, recycling, composting, or combustion. The values in the cells of the matrix are expressed in MTCE/ton in Exhibit 8-13 and in MTCO<sub>2</sub>E/ton in Exhibit 8-14, and represent the *incremental change* in GHG emissions. For example, recycling 1 ton of office paper, rather than landfilling it, reduces GHG emissions by 1.30 MTCE, or 4.76 MTCO<sub>2</sub>E (see the “Recycling” columns of the exhibits). Continuing the example from the previous paragraph, if a business implements an office paper recycling program and annually diverts 10 tons of office paper (that would otherwise be landfilled) to recycling, the GHG emission reductions are:

$$10 \text{ tons/yr} * -1.30 \text{ MTCE/ton} = -13.0 \text{ MTCE/yr}$$

Under the sign convention used in this report, the negative value indicates that emissions are reduced.

Due to resource and data limitations, emission factors have not been developed for all material types reported by WasteWise partners, the Voluntary Reporting of Greenhouse Gas Program—or 1605(b) as it is commonly called—and other parties interested in reporting voluntary emission reductions. However, existing emission factors will continue to be updated and improved and new emission factors will be developed as more data becomes available. The latest emission factors, reflecting these ongoing revisions, can be found on the EPA Global Warming Web site <<http://www.epa.gov/globalwarming/actions/waste/w-online.htm>>.

In cases where parties have been using source reduction or recycling techniques for materials not specifically analyzed in this report, it is possible to estimate the GHG emission reductions by assigning surrogate materials. A list of materials not specifically analyzed, and their corresponding surrogates, is presented in Exhibit 8-15. Surrogates are assigned based on consideration of similarities in characteristics likely to drive life-cycle GHG emissions, such as similarities in energy consumption

during the raw material acquisition and manufacturing life-cycle stages. Note that the use of these surrogates involves considerable uncertainty.

**Exhibit 8-15 Recommended Surrogates for Voluntary Reporting**

<b>Material Source Reduced</b>	<b>Surrogate Material</b>
Metal (type unknown)	Average of Aluminum and Steel
Mixed Metals	Average of Aluminum and Steel
Copper	Steel Cans
Iron	Steel Cans
Other Ferrous Metals	Steel Cans
Other Non-Ferrous Metals	Steel Cans
Steel	Steel Cans
Plastic (resin unknown)	(PET+HDPE+LDPE)/3
PVC/Vinyl	(PET+HDPE+LDPE)/3
Polypropylene	(PET+HDPE+LDPE)/3
Polystyrene	(PET+HDPE+LDPE)/3
Other plastic (resin known, but not 41-46)	(PET+HDPE+LDPE)/3
Rubber	(PET+HDPE+LDPE)/3
Textiles	(PET+HDPE+LDPE)/3
Boxboard	Corrugated Cardboard
Kraft Paper	Corrugated Cardboard
Coated Paper	Magazines/Third-class Mail
High Grade Paper	Office Paper
Paper (type unknown)	Mixed Paper – Broad Definition
Wood	Dimensional Lumber
Food	Food Discards
Organics (type unknown)	Yard Trimmings
Other Yard Waste	Yard Trimmings

In our effort to continually expand and update life-cycle GHG emission factors for MSW materials, we are in the process of developing emission factors for carpet and personal computers. The emission factors will be based on data compiled by Franklin Associates, Ltd. These emission factors will differ from the other emission factors presented in this report because they are for products, each of which contain a variety of individual materials. In turn, the life-cycle emission factors will need to account for GHG emissions associated with the life cycle of each component material. Given the complexity of this task and the relatively limited life-cycle data on components of these products, EPA welcomes input from industry stakeholders to augment or verify the activity data that will be the basis for new emission factors for these products.

### 8.3 OTHER LIFE-CYCLE GHG ANALYSES AND TOOLS

Life-cycle analysis is increasingly being used to quantify the GHG impacts of private and public sector decisions. In addition to the life-cycle analyses that underpin the emission factors in this report, Environmental Defense,<sup>5</sup> ICLEI, Ecobilan, and others have analyzed the life-cycle environmental impacts of various industry processes (e.g., manufacturing) and private and public sector practices (e.g., waste management). In many cases, the results of life-cycle analyses are packaged into life-cycle software tools that distill the information according to a specific user's needs.

As mentioned earlier, the WARM model was designed as a tool for waste managers to weigh the GHG impacts of their waste management practices. As a result, the model focuses exclusively on waste sector GHG emissions, and the methodology used to estimate emissions is consistent with international and domestic GHG accounting guidelines. Life-cycle tools designed for broader audiences necessarily include other sectors and/or other environmental impacts, and are not necessarily tied to the Intergovernmental Panel on Climate Change (IPCC) guidelines for GHG accounting or the methods used in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*.

- WARM covers 21 types of materials and 5 waste management options: source reduction, recycling, combustion, composting, and landfilling. WARM accounts for upstream energy and non-energy emissions, transportation distances to disposal and recycling facilities, carbon sequestration, and utility offsets that result from landfill gas collection and combustion. The tool provides participants in DOE's 1605(b) program with the option to report results by year, by gas, and by year and by gas. WARM software is available free of charge in both a Web-based calculator format and a Microsoft Excel® spreadsheet. The tool is ideal for waste planners interested in tracking and reporting voluntary GHG emission reductions from waste management practices and comparing the climate change impacts of different approaches. To access the tool, visit: <<http://www.epa.gov/globalwarming/actions/waste/warm.htm>>. The latest version of WARM has the additional capacity to calculate energy savings resulting from waste management decisions.
- The Cities for Climate Protection (CCP) Campaign's Greenhouse Gas Emission Software was developed by Torrie Smith Associates for ICLEI. This Windows-based tool, targeted for use by local governments, can analyze emissions and emission reductions on a community-wide basis and for municipal operations alone. The community-wide module looks at residential, commercial, and industrial buildings, transportation activity, and community-generated waste. The municipal operations module considers municipal buildings, municipal fleets, and waste from municipal in-house operations. In addition to computing GHG emissions, the CCP software estimates reductions in criteria air pollutants, changes in energy consumption, and financial costs and savings associated with energy use and other emission reduction initiatives. A version of the software program was made available for use by private businesses and institutions during the summer of 2001. CCP software subscriptions, including technical support, are available to governments participating in ICLEI for a subsidized price of \$240. The full retail price of the software in the United States is \$2,000. For more information, visit: <<http://www.iclei.org/us/ccpsoftware.html>> or contact the U.S. ICLEI office at (510)-540-8843, [iclei\\_usa@iclei.org](mailto:iclei_usa@iclei.org).

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<sup>5</sup> Blum, L., Denison, R.A., and Ruston, V.F. 1997. "A Life-Cycle Approach to Purchasing and Using Environmentally Preferable Paper: A Summary of the Paper Task Force Report," *Journal of Industrial Ecology*; Volume 1; No. 3; pp. 15-46. Denison, R.A. 1996. "Environmental Life-Cycle Comparison of Recycling, Landfilling, and Incineration: A Review of Recent Studies," *Annual Review of Energy and the Environment*; Volume 21, Chapter 6, pp.191-237.

- The MSW Decision Support Tool (DST) and life-cycle inventory database for North America have been developed through funding by EPA's Office of Research and Development (ORD) through a cooperative agreement with the Research Triangle Institute (CR823052). The methodology is based on a multi-media, multi-pollutant approach and includes analysis of GHG emissions as well as a broader set of emissions (air, water, and waste) associated with MSW operations. The MSW-DST is available for site-specific applications and has been used to conduct analyses in several states and 15 communities, including use by the U.S. Navy in the Pacific Northwest. The tool is intended for use by solid waste planners at state and local levels to analyze and compare alternative MSW management strategies with respect to cost, energy consumption, and environmental releases to the air, land, and water. The costs are based on full-cost accounting principles and account for capital and operating costs using an engineering economics analysis. The MSW-DST calculates not only projected emissions of GHGs and criteria air pollutants, but also emissions of more than 30 air- and water-borne pollutants. The DST models emissions associated with all MSW management activities, including waste collection and transportation, transfer stations, materials recovery facilities, compost facilities, landfills, combustion and refuse-derived fuel facilities, utility offsets, material offsets, and source reduction. The differences in residential, multi-family, and commercial sectors can be evaluated individually. The software has optimization capabilities that enable one to identify options that evaluate minimum costs as well as solutions that can maximize environmental benefits, including energy conservation and GHG reductions.

At the time of the publication of this report, the LCI database for North America was to be released in the winter of 2002. All supporting documentation for the MSW-DST and LCI database is to be released by spring 2002. Plans to develop a Web-based version are being considered. The MSW-DST provides extensive default data for the full range of MSW process models and requires minimum input data. The defaults can be tailored to the specific communities using site-specific information. For further information, refer to the project Web site at <http://www.rti.org/units/ese/p2/lca.cfm#life>. The MSW-DST also includes a calculator for source reduction and carbon sequestration using a methodology that is consistent with the IPCC in terms of the treatment of biogenic CO<sub>2</sub> emissions. For more information, refer to the project Web site: <<http://www.rti.org/units/ese/p2/lca.cfm#life>> or contact Susan Thornloe, U.S. EPA, (919)-541-2709, [thornloe.susan@epamail.epa.gov](mailto:thornloe.susan@epamail.epa.gov), or Keith Weitz, Research Triangle Institute, (919)-541-6973, [kaw@rti.org](mailto:kaw@rti.org).

- The Tool for Environmental Analysis and Management (TEAM), developed by Ecobilan, simulates operations associated with product design, processes and, activities associated with several industrial sectors. The model considers energy consumption, material consumption, transportation, waste management, and other factors in its evaluation of environmental impacts. Many firms and some government agencies have used the model. Users pay a licensing fee of \$3,000 and an annual maintenance contract of \$3,000. This model is intended for use in Europe and was not developed for use in North America. For more information, visit: <[http://www.ecobalance.com/software/gb\\_software.html](http://www.ecobalance.com/software/gb_software.html)>.

## 8.4 OPPORTUNITIES FOR GHG REDUCTIONS

Although this report has focused on the five most common waste management practices—source reduction, recycling, composting, combustion, and landfilling—for select materials, future quantification efforts may include a number of emerging practices:

- Co-firing waste biomass. For utilities and power generating companies with coal-fired capacity, co-firing with waste biomass may represent one of the least-cost renewable energy options. Co-firing involves replacing a portion of the coal with biomass at an existing power

plant boiler. This replacement can be achieved by either mixing biomass with coal before fuel is introduced into the boiler or by using separate fuel feeds for coal and biomass. Specific biomass feedstocks include agricultural and wood waste, MSW, and industrial wastes. Given the increasing use of co-firing technology as an energy source, understanding its GHG benefits will likely be an important future EPA effort.

- Compost as landfill cover. Using compost as landfill cover on closed landfills provides an excellent environment for the bacteria that oxidize CH<sub>4</sub>. Under optimal conditions, compost covers can practically eliminate CH<sub>4</sub> emissions. Furthermore, the covers offer the possibility of controlling these emissions in a cost-effective manner. This technology is particularly promising for small landfills, where landfill gas collection is not required and the economics of landfill gas-to-energy projects are not attractive. Ancillary benefits also might arise in the compost market from this technique if using compost as a landfill cover becomes a widespread practice. An increase in composting could reduce the quantity of organic waste disposed of at MSW landfills, thereby reducing CH<sub>4</sub> emissions. Given the recent development of this practice, quantifying its GHG impacts will likely prove useful as landfill owners consider adopting the technology.
- Bioreactors. Bioreactors are a form of controlled landfilling with the potential to provide reliable energy generation from solid waste, as well as significant environmental and solid waste management benefits. The concept is to accelerate the decomposition process of landfill waste through controlled additions of liquid and leachate recirculation, which enhances the growth of the microbes responsible for solid waste decomposition. The result is to shorten the time frame for landfill gas generation, thereby rendering projections of landfill gas generation rates and yields that are much more reliable for landfill gas recovery.
- Anaerobic digestion. Several facilities are using this technique to produce CH<sub>4</sub> from mixed waste, which is then used to fuel energy recovery. The approach generates CH<sub>4</sub> more quickly and captures it more completely than in a landfill environment, and thus, from a GHG perspective, offers a potentially attractive waste management option.<sup>6</sup>
- The paperless office. The rise of computer technology for research, communications, and other everyday workplace functions has presented a major opportunity for source reduction in the modern office. Today's offices are commonly equipped with all the necessary technologies to bypass paper entirely and rely instead on electronic communication. This form of "comprehensive" source reduction comes with significant GHG benefits, as described in Chapter 4. Therefore, attempting to quantify and communicate these benefits to the business community will be an important task in the coming years.
- Product stewardship. Increasingly, companies are taking responsibility for the environmental impacts associated with the full life cycle of their products. Two industries in particular—carpet and electronics—have been on the forefront of product stewardship efforts.

*Carpet:* Currently, more than 6 billion pounds of carpet are shipped each year, of which approximately 200 million pounds are recycled. Although carpet is difficult to recycle due to its varied make-up, any incremental increase in recycling could have significant climate benefits. As a result, EPA is working with a group of carpet industry representatives, state environmental agencies, and non-profit recycling organizations to reach voluntary agreement on a phase-out of carpet disposal. This product stewardship activity has focused on setting rates and dates for carpet recovery over the next 10 years and encouraging the carpet industry

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<sup>6</sup> Environment Canada. 2001. *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions*. Submitted by ICF Consulting, Torrie-Smith Associates, and Enviro-RIS.

to develop a new third-party organization to help coordinate industry efforts. The carpet industry and states have signed a memorandum of understanding that outlines the process and guiding framework for developing a 10-year plan on carpet disposal phase-out. EPA will continue to facilitate this effort in the coming years.<sup>7</sup>

*Electronics:* Understanding GHG emissions associated with waste management options for electronics products is important for a number of reasons. First, electronics are among the most rapidly growing categories of the U.S. waste stream. Sales of electronics have been increasing dramatically, and, due to the fairly short period between purchase and discard, the quantity of electronics discarded is expected to grow significantly in the future. Second, electronics contain valuable materials that can be reused and/or recycled. Third, many electronics products contain toxic materials that are covered by hazardous waste regulations. These three factors have motivated interest on the part of electronics manufacturers, waste managers, and others in recycling. Electronics will therefore become an increasingly essential addition to the list of materials analyzed in this report.

EPA will continue to evaluate new opportunities to reduce emissions from waste management as they become known. We also encourage readers to consider creative approaches to waste management, particularly those with associated life-cycle energy benefits or carbon storage implications.

All of the exhibits presented so far in this report have expressed GHG emissions in units of MTCE or MTCO<sub>2</sub>E, calculated as the sum of the individual gases (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, and PFCs) weighted by their global warming potential. In the Voluntary Reporting of Greenhouse Gas Program—also known as the 1605(b) program—established by DOE’s Energy Information Administration, reporting companies are asked to provide emission reductions for each of the individual gases. In addition, the 1605(b) program requires emission reductions to be reported in the year they are achieved and does not allow participants to take credit for future emission reductions. Because the GHG emission factors presented in this report reflect the “present value” of future emissions and sinks as well as emissions and sinks occurring in the reporting year, our emission factors are not directly transferrable to the 1605(b) program. For purposes of supporting the program, we developed a revised set of 1605(b) program emission factors that reflect emissions by gas and by year. These emission factors provide incremental emissions for a baseline of landfilling and alternative scenarios of source reduction and recycling. Detailed reporting instructions and forms are available on DOE’s Web site at <http://www.eia.doe.gov/oiaf/1605/forms.html>.

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We close with a final note about the limitations of the GHG emission estimates in this report. We based our analysis on what we believed to be the best available data; where necessary, we made assumptions that we believe are reasonable. The accuracy of the estimates is limited, however, by the use of these assumptions and limitations in the data sources, as discussed throughout this report. Where possible, the emission factors reported here can be improved by substituting process- or site-specific data to increase the accuracy of the estimates. For example, a commercial firm with a large aluminum recycling program may have better data on the specific fuel mix of its source of aluminum and could thus calculate a more exact value for the emission factor. Despite the uncertainty in the emission factors, they provide a reasonable first approximation of the GHG impacts of solid waste management, and we believe that they provide a sound basis for evaluating voluntary actions to reduce GHG emissions in the waste management arena.

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<sup>7</sup> Additional information on this activity is available on the Minnesota Office of Environmental Assistance Web site at <http://www.moea.state.mn.us/carpet/care.cfm>.



**Exhibit 8-1**  
**GHG Emissions for Source Reduction**  
**(MTCE/Ton of Material Source Reduced)**

Emissions Measured from a Waste Generation Reference Point<sup>1</sup>

Material	(a) Raw Materials Acquisition and Manufacturing		(b) Forest Carbon Sequestration		(c)  Waste Management Emissions	(d = a + b + c)	
						(d) Net Emissions	
	Source Reduction Displaces Current Mix of Virgin and Recycled Inputs	Source Reduction Displaces Virgin Inputs	Source Reduction Displaces Current Mix of Virgin and Recycled Inputs	Source Reduction Displaces Virgin Inputs		Source Reduction Displaces Current Mix of Virgin and Recycled Inputs	Source Reduction Displaces Virgin Inputs
Aluminum Cans	-2.49	-4.67	0.00	0.00	0.00	-2.49	-4.67
Steel Cans	-0.79	-1.01	0.00	0.00	0.00	-0.79	-1.01
Glass	-0.14	-0.16	0.00	0.00	0.00	-0.14	-0.16
HDPE	-0.49	-0.53	0.00	0.00	0.00	-0.49	-0.53
LDPE	-0.61	-0.64	0.00	0.00	0.00	-0.61	-0.64
PET	-0.49	-0.58	0.00	0.00	0.00	-0.49	-0.58
Corrugated Cardboard	-0.24	-0.22	-0.28	-0.73	0.00	-0.51	-0.96
Magazines/Third-class Mail	-0.46	-0.46	-0.58	-0.73	0.00	-1.04	-1.19
Newspaper	-0.46	-0.59	-0.35	-0.73	0.00	-0.81	-1.32
Office Paper	-0.31	-0.28	-0.50	-0.73	0.00	-0.80	-1.01
Phonebooks	-0.64	-0.67	-0.65	-0.73	0.00	-1.28	-1.40
Textbooks	-0.59	-0.59	-0.64	-0.73	0.00	-1.23	-1.32
Dimensional Lumber	-0.05	-0.05	-0.50	-0.50	0.00	-0.55	-0.55
Medium-density Fiberboard	-0.10	-0.10	-0.50	-0.50	0.00	-0.60	-0.60
Food Discards	NA	NA	NA	NA	NA	NA	NA
Yard Trimmings	NA	NA	NA	NA	NA	NA	NA
Mixed Paper							
Broad Definition	NA	NA	NA	NA	NA	NA	NA
Residential Definition	NA	NA	NA	NA	NA	NA	NA
Office Paper Definition	NA	NA	NA	NA	NA	NA	NA
Mixed Plastics	NA	NA	NA	NA	NA	NA	NA
Mixed Recyclables	NA	NA	NA	NA	NA	NA	NA
Mixed Organics	NA	NA	NA	NA	NA	NA	NA
Mixed MSW (as disposed)	NA	NA	NA	NA	NA	NA	NA

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Under the accounting convention used in this analysis, emissions are quantified from a waste generation reference point (once the material has already undergone the raw materials acquisition and manufacturing phase).

**Exhibit 8-2**  
**GHG Emissions for Source Reduction**  
**(MTCO<sub>2</sub>E/Ton of Material Source Reduced)**  
Emissions Measured from a Waste Generation Reference Point<sup>1</sup>

Material	(a) Raw Materials Acquisition and Manufacturing		(b) Forest Carbon Sequestration		(c)  Waste Management Emissions	(d = a + b + c)  (d) Net Emissions	
	Source Reduction Displaces Current Mix of Virgin and Recycled Inputs	Source Reduction Displaces Virgin Inputs	Source Reduction Displaces Current Mix of Virgin and Recycled Inputs	Source Reduction Displaces Virgin Inputs		Source Reduction Displaces Current Mix of Virgin and Recycled Inputs	Source Reduction Displaces Virgin Inputs
Aluminum Cans	-9.15	-17.11	0.00	0.00	0.00	-9.15	-17.11
Steel Cans	-2.89	-3.69	0.00	0.00	0.00	-2.89	-3.69
Glass	-0.50	-0.57	0.00	0.00	0.00	-0.50	-0.57
HDPE	-1.79	-1.95	0.00	0.00	0.00	-1.79	-1.95
LDPE	-2.25	-2.34	0.00	0.00	0.00	-2.25	-2.34
PET	-1.78	-2.14	0.00	0.00	0.00	-1.78	-2.14
Corrugated Cardboard	-0.88	-0.82	-1.01	-2.69	0.00	-1.89	-3.50
Magazines/Third-class Mail	-1.69	-1.69	-2.11	-2.69	0.00	-3.80	-4.38
Newspaper	-1.69	-2.15	-1.29	-2.69	0.00	-2.97	-4.84
Office Paper	-1.13	-1.02	-1.82	-2.69	0.00	-2.95	-3.71
Phonebooks	-2.33	-2.44	-2.37	-2.69	0.00	-4.70	-5.13
Textbooks	-2.15	-2.16	-2.35	-2.69	0.00	-4.49	-4.85
Dimensional Lumber	-0.17	-0.17	-1.84	-1.84	0.00	-2.01	-2.01
Medium-density Fiberboard	-0.36	-0.36	-1.84	-1.84	0.00	-2.20	-2.20
Food Discards	NA	NA	NA	NA	NA	NA	NA
Yard Trimmings	NA	NA	NA	NA	NA	NA	NA
Mixed Paper							
Broad Definition	NA	NA	NA	NA	NA	NA	NA
Residential Definition	NA	NA	NA	NA	NA	NA	NA
Office Paper Definition	NA	NA	NA	NA	NA	NA	NA
Mixed Plastics	NA	NA	NA	NA	NA	NA	NA
Mixed Recyclables	NA	NA	NA	NA	NA	NA	NA
Mixed Organics	NA	NA	NA	NA	NA	NA	NA
Mixed MSW (as disposed)	NA	NA	NA	NA	NA	NA	NA

Note that totals may not add due to rounding and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Under the accounting convention used in this analysis, emissions are quantified from a waste generation reference point (once the material has already undergone the raw materials acquisition and manufacturing phase).

**Exhibit 8-3**  
**Recycling**  
**(GHG Emissions in MTCE/Ton)**

Emissions Measured from a Waste Generation Reference Point<sup>1</sup>

	Raw Materials Acquisition and Manufacturing (RMAM)		Recycled Input Credit <sup>2</sup>			(f)	(g)	(h) (h = b+c+d+e+f+g)
	(a)	(b)	(c)	(d)	(e)			
Material	RMAM Emissions Not Included in Baseline <sup>3</sup> (current mix of inputs)	Waste Generation Baseline	Process Energy	Transportation Energy	Process Non-Energy	Forest Carbon Sequestration	Waste Management Emissions	Net Emissions
Aluminum Cans	2.49	0.00	-2.92	-0.14	-1.05	0.00	0.00	-4.11
Steel Cans	0.79	0.00	-0.48	-0.01	0.00	0.00	0.00	-0.49
Glass	0.14	0.00	-0.03	0.00	-0.04	0.00	0.00	-0.08
HDPE	0.49	0.00	-0.34	0.00	-0.04	0.00	0.00	-0.38
LDPE	0.61	0.00	-0.43	0.00	-0.04	0.00	0.00	-0.47
PET	0.49	0.00	-0.40	0.00	-0.02	0.00	0.00	-0.42
Corrugated Cardboard	0.24	0.00	0.04	-0.01	0.00	-0.73	0.00	-0.71
Magazines/Third-class Mail	0.46	0.00	0.00	0.00	0.00	-0.73	0.00	-0.74
Newspaper	0.46	0.00	-0.21	-0.01	0.00	-0.73	0.00	-0.95
Office Paper	0.31	0.00	0.06	0.00	0.00	-0.73	0.00	-0.68
Phonebooks	0.64	0.00	-0.18	0.00	0.00	-0.73	0.00	-0.91
Textbooks	0.59	0.00	-0.01	0.00	0.00	-0.73	0.00	-0.75
Dimensional Lumber	0.05	0.00	0.02	0.00	0.00	-0.69	0.00	-0.67
Medium-density Fiberboard	0.10	0.00	0.01	0.00	0.00	-0.69	0.00	-0.67
Food Discards	NA	0.00	NA	NA	NA	NA	0.00	NA
Yard Trimmings	NA	0.00	NA	NA	NA	NA	0.00	NA
Mixed Paper								
Broad Definition	0.38	0.00	0.08	-0.02	0.00	-0.73	0.00	-0.67
Residential Definition	0.38	0.00	0.08	-0.02	0.00	-0.73	0.00	-0.67
Office Paper Definition	0.85	0.00	-0.08	-0.02	0.00	-0.73	0.00	-0.83
Mixed Plastics	0.51	0.00	-0.38	0.00	-0.03	0.00	0.00	-0.41
Mixed Recyclables	0.36	0.00	-0.10	-0.01	-0.02	-0.63	0.00	-0.76
Mixed Organics	NA	NA	NA	NA	NA	NA	NA	NA
Mixed MSW (as disposed)	NA	NA	NA	NA	NA	NA	NA	NA

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Under the accounting convention used in this analysis, emissions are quantified from a waste generation reference point (once the material has already undergone the raw materials acquisition and manufacturing phase).

<sup>2</sup>Material that is recycled after use is then substituted for virgin inputs in the production of new products. This credit represents the difference in emissions that results from using recycled inputs

**Exhibit 8-4**  
**Recycling**  
**(GHG Emissions in MTCO<sub>2</sub>E/Ton)**

Emissions Measured from a Waste Generation Reference Point<sup>1</sup>

Material	Raw Materials Acquisition and Manufacturing (RMAM)		Recycled Input Credit <sup>2</sup>			(f)	(g)	(h) (h = b+c+d+e+f+g)
	(a)  RMAM Emissions Not Included in Baseline <sup>3</sup> (Current Mix of Inputs)	(b)  Waste Generation Baseline	(c)  Process Energy	(d)  Transportation Energy	(e)  Process Non- Energy			
Aluminum Cans	9.15	0.00	-10.70	-0.51	-3.86	0.00	0.00	-15.07
Steel Cans	2.89	0.00	-1.75	-0.04	0.00	0.00	0.00	-1.79
Glass	0.50	0.00	-0.12	-0.02	-0.14	0.00	0.00	-0.28
HDPE	1.79	0.00	-1.26	0.00	-0.15	0.00	0.00	-1.40
LDPE	2.25	0.00	-1.57	0.00	-0.15	0.00	0.00	-1.71
PET	1.78	0.00	-1.48	0.00	-0.08	0.00	0.00	-1.55
Corrugated Cardboard	0.88	0.00	0.13	-0.04	-0.01	-2.69	0.00	-2.60
Magazines/Third Class Mail	1.69	0.00	-0.01	0.00	0.00	-2.69	0.00	-2.70
Newspaper	1.69	0.00	-0.76	-0.03	0.00	-2.69	0.00	-3.48
Office Paper	1.13	0.00	0.22	0.00	-0.02	-2.69	0.00	-2.48
Phonebooks	2.33	0.00	-0.65	0.00	0.00	-2.69	0.00	-3.34
Textbooks	2.15	0.00	-0.05	0.00	0.00	-2.69	0.00	-2.74
Dimensional Lumber	0.17	0.00	0.07	0.01	0.00	-2.53	0.00	-2.45
Medium-density Fiberboard	0.36	0.00	0.05	0.02	0.00	-2.53	0.00	-2.47
Food Discards	NA	0.00	NA	NA	NA	NA	0.00	NA
Yard Trimmings	NA	0.00	NA	NA	NA	NA	0.00	NA
Mixed Paper		0.00						
Broad Definition	1.38	0.00	0.29	-0.06	0.00	-2.69	0.00	-2.47
Residential Definition	1.39	0.00	0.29	-0.06	0.00	-2.69	0.00	-2.47
Office Paper Definition	3.12	0.00	-0.29	-0.07	0.00	-2.69	0.00	-3.05
Mixed Plastics	1.85	0.00	-1.40	0.00	-0.12	0.00	0.00	-1.51
Mixed Recyclables	1.32	0.00	-0.38	-0.04	-0.09	-2.30	0.00	-2.80
Mixed Organics	NA	NA	NA	NA	NA	NA	NA	NA
Mixed MSW (as disposed)	NA	NA	NA	NA	NA	NA	NA	NA

Note that totals may not add due to rounding and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Under the accounting convention used in this analysis, emissions are quantified from a waste generation reference point (once the material has already undergone the raw materials acquisition and manufacturing phase).

<sup>2</sup> Material that is recycled after use is then substituted for virgin inputs in the production of new products. This credit represents the difference in emissions that results from using recycled inputs

**Exhibit 8-5**  
**Composting**  
**(GHG Emissions in MTCE/Ton)**

Values are for Mass Burn Facilities with National Average Rate of Ferrous Recovery. Emissions Measured from a Waste Generation Reference Point<sup>1</sup>

	Raw Materials Acquisition and Manufacturing (RMAM)		(c)	(d)	(e) (e = b+c+d)
	(a)	(b)			
Material	RMAM Emissions Not Included in Baseline <sup>2</sup>	Waste Generation Baseline	Transportation to Composting	Soil Carbon Sequestration	Net Emissions (Post-Consumer)
Aluminum Cans	-2.49	0.00	NA	NA	NA
Steel Cans	-0.79	0.00	NA	NA	NA
Glass	-0.14	0.00	NA	NA	NA
HDPE	-0.49	0.00	NA	NA	NA
LDPE	-0.61	0.00	NA	NA	NA
PET	-0.49	0.00	NA	NA	NA
Corrugated Cardboard	-0.24	0.00	NA	NA	NA
Magazines/Third-class Mail	-0.46	0.00	NA	NA	NA
Newspaper	-0.46	0.00	NA	NA	NA
Office Paper	-0.31	0.00	NA	NA	NA
Phonebooks	-0.64	0.00	NA	NA	NA
Textbooks	-0.59	0.00	NA	NA	NA
Dimensional Lumber	-0.05	0.00	NA	NA	NA
Medium-density Fiberboard	-0.10	0.00	NA	NA	NA
Food Discards	NA	0.00	0.01	-0.07	-0.05
Yard Trimmings	NA	0.00	0.01	-0.07	-0.05
Mixed Paper					
Broad Definition	0.38	0.00	NA	NA	NA
Residential Definition	0.38	0.00	NA	NA	NA
Office Paper Definition	0.85	0.00	NA	NA	NA
Mixed Plastics	0.51	0.00	NA	NA	NA
Mixed Recyclables	0.36	0.00	NA	NA	NA
Mixed Organics	NA	0.00	0.01	-0.07	-0.05
Mixed MSW (as disposed)	NA	NA	NA	NA	NA

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Under the accounting convention used in this analysis, emissions are quantified from a waste generation reference point (once the material has already undergone the raw materials acquisition and manufacturing phase).

<sup>2</sup> The value for mixed MSW is the weighted average of the RMAM emissions for those materials we studied.

**Exhibit 8-6**  
**Composting**  
**(GHG Emissions in MTCO<sub>2</sub>E/Ton)**

Values are for Mass Burn Facilities with National Average Rate of Ferrous Recovery. Emissions Measured from a Waste Generation Reference Point<sup>1</sup>

	Raw Materials Acquisition and Manufacturing (RMAM)		(c)	(d)	(e) (e = b+c+d)
	(a)	(b)			
Material	RMAM Emissions Not Included in Baseline <sup>2</sup>	Waste Generation Baseline	Transportation to Composting	Soil Carbon Sequestration	Net Emissions (Post-Consumer)
Aluminum Cans	-9.15	0.00	NA	NA	NA
Steel Cans	-2.89	0.00	NA	NA	NA
Glass	-0.50	0.00	NA	NA	NA
HDPE	-1.79	0.00	NA	NA	NA
LDPE	-2.25	0.00	NA	NA	NA
PET	-1.78	0.00	NA	NA	NA
Corrugated Cardboard	-0.88	0.00	NA	NA	NA
Magazines/Third-class Mail	-1.69	0.00	NA	NA	NA
Newspaper	-1.69	0.00	NA	NA	NA
Office Paper	-1.13	0.00	NA	NA	NA
Phonebooks	-2.33	0.00	NA	NA	NA
Textbooks	-2.15	0.00	NA	NA	NA
Dimensional Lumber	-0.17	0.00	NA	NA	NA
Medium-density Fiberboard	-0.36	0.00	NA	NA	NA
Food Discards	NA	0.00	0.04	-0.24	-0.20
Yard Trimmings	NA	0.00	0.04	-0.24	-0.20
Mixed Paper		0.00			
Broad Definition	1.38	0.00	NA	NA	NA
Residential Definition	1.39	0.00	NA	NA	NA
Office Paper Definition	3.12	0.00	NA	NA	NA
Mixed Plastics	1.85	0.00	NA	NA	NA
Mixed Recyclables	1.32	0.00	NA	NA	NA
Mixed Organics	NA	0.00	0.04	-0.24	-0.20
Mixed MSW (as disposed)	NA	NA	NA	NA	NA

Note that totals may not add due to rounding and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Under the accounting convention used in this analysis, emissions are quantified from a waste generation reference point (once the material has already undergone the raw materials acquisition and manufacturing phase).

<sup>2</sup> The value for mixed MSW is the weighted average of the RMAM emissions for those materials we studied.

**Exhibit 8-7**  
**Combustion**  
**(GHG Emissions in MTCE/Ton)**

Values are for Mass Burn Facilities with National Average Rate of Ferrous Recovery. Emissions Measured from a Waste Generation Reference Point<sup>1</sup>

	Raw Materials Acquisition and Manufacturing (RMAM)		(c)	(d)	(e)	(f)	(g)	(h) (h = b+c+d+e+f+g)
	(a)	(b)						
Material	RMAM Emissions Not Included in Baseline <sup>2</sup>	Waste Generation Baseline	Transportation to Combustion	CO <sub>2</sub> from Combustion	N <sub>2</sub> O from Combustion	Avoided Utility Emissions	Ferrous Recovery	Net Emissions (Post-Consumer)
Aluminum Cans	-2.49	0.00	0.01	0.00	0.00	0.01	0.00	0.02
Steel Cans	-0.79	0.00	0.01	0.00	0.00	0.01	-0.43	-0.42
Glass	-0.14	0.00	0.01	0.00	0.00	0.01	0.00	0.01
HDPE	-0.49	0.00	0.01	0.76	0.00	-0.54	0.00	0.23
LDPE	-0.61	0.00	0.01	0.76	0.00	-0.54	0.00	0.23
PET	-0.49	0.00	0.01	0.56	0.00	-0.28	0.00	0.28
Corrugated Cardboard	-0.24	0.00	0.01	0.00	0.01	-0.20	0.00	-0.19
Magazines/Third-class Mail	-0.46	0.00	0.01	0.00	0.01	-0.15	0.00	-0.13
Newspaper	-0.46	0.00	0.01	0.00	0.01	-0.23	0.00	-0.21
Office Paper	-0.31	0.00	0.01	0.00	0.01	-0.20	0.00	-0.18
Phonebooks	-0.64	0.00	0.01	0.00	0.01	-0.23	0.00	-0.21
Textbooks	-0.59	0.00	0.01	0.00	0.01	-0.20	0.00	-0.18
Dimensional Lumber	-0.05	0.00	0.01	0.00	0.01	-0.24	0.00	-0.22
Medium-density Fiberboard	-0.10	0.00	0.01	0.00	0.01	-0.24	0.00	-0.22
Food Discards	NA	0.00	0.01	0.00	0.01	-0.07	0.00	-0.05
Yard Trimmings	NA	0.00	0.01	0.00	0.01	-0.08	0.00	-0.06
Mixed Paper								
Broad Definition	0.38	0.00	0.01	0.00	0.01	-0.20	0.00	-0.19
Residential Definition	0.38	0.00	0.01	0.00	0.01	-0.20	0.00	-0.18
Office Paper Definition	0.85	0.00	0.01	0.00	0.01	-0.19	0.00	-0.17
Mixed Plastics	0.51	0.00	0.01	0.67	0.00	-0.43	0.00	0.25
Mixed Recyclables	0.36	0.00	0.01	0.02	0.01	-0.18	-0.02	-0.17
Mixed Organics	NA	0.00	0.01	0.00	0.01	-0.07	0.00	-0.06
Mixed MSW (as disposed)	NA	0.00	0.01	0.10	0.01	-0.14	-0.01	-0.04

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Under the accounting convention used in this analysis, emissions are quantified from a waste generation reference point (once the material has already undergone the raw materials acquisition and manufacturing phase).

<sup>2</sup> The value for mixed MSW is the weighted average of the RMAM emissions for those materials we studied.

**Exhibit 8-8**  
**Combustion**  
**(GHG Emissions in MTCO<sub>2</sub>E/Ton)**

Values are for Mass Burn Facilities with National Average Rate of Ferrous Recovery. Emissions Measured from a Waste Generation Reference Point<sup>1</sup>

Material	Raw Materials Acquisition and Manufacturing (RMAM)		(c)	(d)	(e)	(f)	(g)	(h) (h = b+c+d+e+f+g)
	(a)  RMAM Emissions Not Included in Baseline <sup>2</sup>	(b)  Waste Generation Baseline						
			Transportation to Combustion	CO <sub>2</sub> from Combustion	N <sub>2</sub> O from Combustion	Avoided Utility Emissions	Ferrous Recovery	Net Emissions (Post-Consumer)
Aluminum Cans	-9.15	0.00	0.03	0.00	0.00	0.04	0.00	0.06
Steel Cans	-2.89	0.00	0.03	0.00	0.00	0.02	-1.58	-1.53
Glass	-0.50	0.00	0.03	0.00	0.00	0.02	0.00	0.05
HDPE	-1.79	0.00	0.03	2.79	0.00	-1.97	0.00	0.85
LDPE	-2.25	0.00	0.03	2.79	0.00	-1.97	0.00	0.85
PET	-1.78	0.00	0.03	2.04	0.00	-1.02	0.00	1.04
Corrugated Cardboard	-0.88	0.00	0.03	0.00	0.04	-0.74	0.00	-0.68
Magazines/Third-class Mail	-1.69	0.00	0.03	0.00	0.04	-0.55	0.00	-0.49
Newspaper	-1.69	0.00	0.03	0.00	0.04	-0.84	0.00	-0.77
Office Paper	-1.13	0.00	0.03	0.00	0.04	-0.72	0.00	-0.65
Phonebooks	-2.33	0.00	0.03	0.00	0.04	-0.84	0.00	-0.77
Textbooks	-2.15	0.00	0.03	0.00	0.04	-0.72	0.00	-0.65
Dimensional Lumber	-0.17	0.00	0.03	0.00	0.04	-0.87	0.00	-0.81
Medium-density Fiberboard	-0.36	0.00	0.03	0.00	0.04	-0.87	0.00	-0.81
Food Discards	NA	0.00	0.03	0.00	0.04	-0.25	0.00	-0.19
Yard Trimmings	NA	0.00	0.03	0.00	0.04	-0.30	0.00	-0.23
Mixed Paper								
Broad Definition	1.38	0.00	0.03	0.00	0.04	-0.74	0.00	-0.68
Residential Definition	1.39	0.00	0.03	0.00	0.04	-0.74	0.00	-0.68
Office Paper Definition	3.12	0.00	0.03	0.00	0.04	-0.68	0.00	-0.62
Mixed Plastics	1.85	0.00	0.03	2.47	0.00	-1.56	0.00	0.93
Mixed Recyclables	1.32	0.00	0.03	0.06	0.03	-0.67	-0.06	-0.61
Mixed Organics	NA	0.00	0.03	0.00	0.04	-0.27	0.00	-0.21
Mixed MSW (as disposed)	NA	0.00	0.03	0.37	0.04	-0.53	-0.04	-0.13

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Under the accounting convention used in this analysis, emissions are quantified from a waste generation reference point (once the material has already undergone the raw materials acquisition and manufacturing phase).

<sup>2</sup> The value for mixed MSW is the weighted average of the RMAM emissions for those materials we studied.

**Exhibit 8-9**  
**Landfilling**  
**(GHG Emissions in MTCE/Ton)**

Values for Landfill Methane and Net Emissions Reflect Projected National Average Methane Recovery in year 2000. Emissions Measured from a Waste Generation Reference Point<sup>1</sup>

	Raw Materials Acquisition and Manufacturing (RMAM)		(c)	(d)	(e)	(f) (f=b+c+d+e)
	(a)	(b)				
Material	RMAM Emissions Not Included in Baseline <sup>2</sup>	Waste Generation Baseline	Transportation to Landfill	Net Landfill CH <sub>4</sub>	Landfill Carbon Sequestration	Net Emissions
Aluminum Cans	2.49	0.00	0.01	0.00	0.00	0.01
Steel Cans	0.79	0.00	0.01	0.00	0.00	0.01
Glass	0.14	0.00	0.01	0.00	0.00	0.01
HDPE	0.49	0.00	0.01	0.00	0.00	0.01
LDPE	0.61	0.00	0.01	0.00	0.00	0.01
PET	0.49	0.00	0.01	0.00	0.00	0.01
Corrugated Cardboard	0.24	0.00	0.01	0.31	-0.22	0.09
Magazines/Third-class Mail	0.46	0.00	0.01	0.17	-0.29	-0.11
Newspaper	0.46	0.00	0.01	0.15	-0.36	-0.20
Office Paper	0.31	0.00	0.01	0.69	-0.04	0.66
Phonebooks	0.64	0.00	0.01	0.15	-0.36	-0.20
Textbooks	0.59	0.00	0.01	0.69	-0.04	0.66
Dimensional Lumber	0.05	0.00	0.01	0.10	-0.21	-0.10
Medium-density Fiberboard	0.10	0.00	0.01	0.10	-0.21	-0.10
Food Discards	NA	0.00	0.01	0.19	-0.02	0.18
Yard Trimmings	NA	0.00	0.01	0.11	-0.21	-0.09
Mixed Paper						
Broad Definition	0.38	0.00	0.01	0.33	-0.23	0.12
Residential Definition	0.38	0.00	0.01	0.31	-0.24	0.08
Office Paper Definition	0.85	0.00	0.01	0.37	-0.21	0.17
Mixed Plastics	0.51	0.00	0.01	0.00	0.00	0.01
Mixed Recyclables	0.36	0.00	0.01	0.26	-0.21	0.06
Mixed Organics	NA	0.00	0.01	0.15	-0.12	0.04
Mixed MSW (as disposed)	NA	0.00	0.01	0.16	-0.10	0.07

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Under the accounting convention used in this analysis, emissions are quantified from a waste generation reference point (once the material has already undergone the raw materials acquisition and manufacturing phase).

<sup>2</sup>The value for mixed MSW is the weighted average of the RMAM emissions for those materials we studied.

**Exhibit 8-10**  
**Landfilling**  
**(GHG Emissions in MTCO<sub>2</sub>E/Ton)**

Values for Landfill Methane and Net Emissions Reflect Projected National Average Methane Recovery in year 2000. Emissions Measured from a Waste Generation Reference Point<sup>1</sup>

	Raw Materials Acquisition and Manufacturing (RMAM)		(c)	(d)	(e)	(f)
	(a)	(b)				
Material	RMAM Emissions Not Included in Baseline <sup>2</sup>	Waste Generation Baseline	Transportation to Landfill	Net Landfill CH <sub>4</sub>	Landfill Carbon Sequestration	(f=b+c+d+e) Net Emissions
Aluminum Cans	9.15	0.00	0.04	0.00	0.00	0.04
Steel Cans	2.89	0.00	0.04	0.00	0.00	0.04
Glass	0.50	0.00	0.04	0.00	0.00	0.04
HDPE	1.79	0.00	0.04	0.00	0.00	0.04
LDPE	2.25	0.00	0.04	0.00	0.00	0.04
PET	1.78	0.00	0.04	0.00	0.00	0.04
Corrugated Cardboard	0.88	0.00	0.04	1.12	-0.82	0.34
Magazines/Third-class Mail	1.69	0.00	0.04	0.61	-1.07	-0.41
Newspaper	1.69	0.00	0.04	0.54	-1.32	-0.74
Office Paper	1.13	0.00	0.04	2.52	-0.16	2.40
Phonebooks	2.33	0.00	0.04	0.54	-1.32	-0.74
Textbooks	2.15	0.00	0.04	2.52	-0.16	2.40
Dimensional Lumber	0.17	0.00	0.04	0.35	-0.76	-0.37
Medium-density Fiberboard	0.36	0.00	0.04	0.35	-0.76	-0.37
Food Discards	NA	0.00	0.04	0.70	-0.08	0.66
Yard Trimmings	NA	0.00	0.04	0.40	-0.76	-0.33
Mixed Paper						
Broad Definition	1.38	0.00	0.04	1.22	-0.83	0.43
Residential Definition	1.39	0.00	0.04	1.13	-0.87	0.30
Office Paper Definition	3.12	0.00	0.04	1.35	-0.76	0.63
Mixed Plastics	1.85	0.00	0.04	0.00	0.00	0.04
Mixed Recyclables	1.32	0.00	0.04	0.95	-0.75	0.24
Mixed Organics	NA	0.00	0.04	0.54	-0.43	0.15
Mixed MSW (as disposed)	NA	0.00	0.04	0.60	-0.37	0.27

Note that totals may not add due to rounding and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Under the accounting convention used in this analysis, emissions are quantified from a waste generation reference point (once the material has already undergone the raw materials acquisition and manufacturing phase).

<sup>2</sup>The value for mixed MSW is the weighted average of the RMAM emissions for those materials we studied.

**Exhibit 8-11**  
**Net GHG Emissions from Source Reduction and MSW Management Options**  
**(MTCE/Ton)**

Emissions Measured from a Waste Generation Reference Point<sup>1</sup>

<b>Material</b>	<b>Source Reduction<sup>2</sup></b>	<b>Recycling</b>	<b>Composting</b>	<b>Combustion<sup>3</sup></b>	<b>Landfilling<sup>4</sup></b>
Aluminum Cans	-2.49	-4.11	NA	0.02	0.01
Steel Cans	-0.79	-0.49	NA	-0.42	0.01
Glass	-0.14	-0.08	NA	0.01	0.01
HDPE	-0.49	-0.38	NA	0.23	0.01
LDPE	-0.61	-0.47	NA	0.23	0.01
PET	-0.49	-0.42	NA	0.28	0.01
Corrugated Cardboard	-0.51	-0.71	NA	-0.19	0.08
Magazines/Third-class Mail	-1.04	-0.74	NA	-0.13	-0.12
Newspaper	-0.81	-0.95	NA	-0.21	-0.21
Office Paper	-0.80	-0.68	NA	-0.18	0.62
Phonebooks	-1.28	-0.91	NA	-0.21	-0.21
Textbooks	-1.23	-0.75	NA	-0.18	0.62
Dimensional Lumber	-0.55	-0.67	NA	-0.22	-0.10
Medium-density Fiberboard	-0.60	-0.67	NA	-0.22	-0.10
Food Discards	NA	NA	-0.05	-0.05	0.17
Yard Trimmings	NA	NA	-0.05	-0.06	-0.09
Mixed Paper					
Broad Definition	NA	-0.67	NA	-0.19	0.10
Residential Definition	NA	-0.67	NA	-0.18	0.07
Office Paper Definition	NA	-0.83	NA	-0.17	0.15
Mixed Plastics	NA	-0.41	NA	0.25	0.01
Mixed Recyclables	NA	-0.76	NA	-0.17	0.05
Mixed Organics	NA	NA	-0.05	-0.06	0.03
Mixed MSW (as disposed)	NA	NA	NA	-0.04	0.07

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Under the accounting convention used in this analysis, emissions are quantified from a waste generation reference point (once the material has already undergone the raw materials acquisition and manufacturing phase).

<sup>2</sup> Source reduction assumes displacement of current mix of virgin and recycled inputs.

<sup>3</sup> Values are for mass burn facilities with national average rate of ferrous recovery.

<sup>4</sup> Values reflect projected national average methane recovery in year 2000.

**Exhibit 8-12**  
**Net GHG Emissions from Source Reduction and MSW Management Options**  
**(MTCO<sub>2</sub>E/Ton)**

Emissions Measured from a Waste Generation Reference Point<sup>1</sup>

<b>Material</b>	<b>Source Reduction<sup>2</sup></b>	<b>Recycling</b>	<b>Composting</b>	<b>Combustion<sup>3</sup></b>	<b>Landfilling<sup>4</sup></b>
Aluminum Cans	-9.15	-15.07	NA	0.06	0.04
Steel Cans	-2.89	-1.79	NA	-1.53	0.04
Glass	-0.50	-0.28	NA	0.05	0.04
HDPE	-1.79	-1.40	NA	0.85	0.04
LDPE	-2.25	-1.71	NA	0.85	0.04
PET	-1.78	-1.55	NA	1.04	0.04
Corrugated Cardboard	-1.89	-2.60	NA	-0.68	0.28
Magazines/Third-class Mail	-3.80	-2.70	NA	-0.49	-0.44
Newspaper	-2.97	-3.48	NA	-0.77	-0.76
Office Paper	-2.95	-2.48	NA	-0.65	2.28
Phonebooks	-4.70	-3.34	NA	-0.77	-0.76
Textbooks	-4.49	-2.74	NA	-0.65	2.28
Dimensional Lumber	-2.01	-2.45	NA	-0.81	-0.38
Medium-density Fiberboard	-2.20	-2.47	NA	-0.81	-0.38
Food Discards	NA	NA	-0.20	-0.19	0.62
Yard Trimmings	NA	NA	-0.20	-0.23	-0.34
Mixed Paper					
Broad Definition	NA	-2.47	NA	-0.68	0.37
Residential Definition	NA	-2.47	NA	-0.68	0.25
Office Paper Definition	NA	-3.05	NA	-0.62	0.56
Mixed Plastics	NA	-1.51	NA	0.93	0.04
Mixed Recyclables	NA	-2.80	NA	-0.61	0.19
Mixed Organics	NA	NA	-0.20	-0.21	0.12
Mixed MSW (as disposed)	NA	NA	NA	-0.13	0.24

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Under the accounting convention used in this analysis, emissions are quantified from a waste generation reference point (once the material has already undergone the raw materials acquisition and manufacturing phase).

<sup>2</sup> Source reduction assumes displacement of current mix of virgin and recycled inputs.

<sup>3</sup> Values are for mass burn facilities with national average rate of ferrous recovery.

<sup>4</sup> Values reflect projected national average methane recovery in year 2000.

**Exhibit 8-13**  
**Net GHG Emissions of MSW Management Options Compared to Landfilling<sup>1</sup>**  
**(MTCE/Ton)**

Negative values indicate emission reductions.

Material	Source Reduction Net Emissions		Recycling Net Emissions	Composting Net Emissions	Combustion <sup>2</sup> Net Emissions
	Minus Landfilling Net Emissions		Minus Landfilling Net Emissions	Minus Landfilling Net Emissions	Minus Landfilling Net Emissions
	Current Mix of Inputs	100% Virgin Inputs			
Aluminum Cans	-2.50	-4.68	-4.12	NA	0.01
Steel Cans	-0.80	-1.02	-0.50	NA	-0.43
Glass	-0.15	-0.17	-0.09	NA	0.00
HDPE	-0.50	-0.54	-0.39	NA	0.22
LDPE	-0.63	-0.65	-0.48	NA	0.22
PET	-0.50	-0.59	-0.43	NA	0.27
Corrugated Cardboard	-0.59	-1.03	-0.79	NA	-0.26
Magazines/Third-class Mail	-0.92	-1.07	-0.62	NA	-0.01
Newspaper	-0.60	-1.11	-0.74	NA	0.00
Office Paper	-1.43	-1.63	-1.30	NA	-0.80
Phonebooks	-1.07	-1.19	-0.70	NA	0.00
Textbooks	-1.85	-1.94	-1.37	NA	-0.80
Dimensional Lumber	-0.44	-0.44	-0.56	NA	-0.12
Medium-density Fiberboard	-0.50	-0.50	-0.57	NA	-0.12
Food Discards	NA	NA	NA	-0.22	-0.22
Yard Trimmings	NA	NA	NA	0.04	0.03
Mixed Paper					
Broad Definition	NA	NA	-0.78	NA	-0.29
Residential Definition	NA	NA	-0.74	NA	-0.25
Office Paper Definition	NA	NA	-0.99	NA	-0.32
Mixed Plastics	NA	NA	-0.42	NA	0.24
Mixed Recyclables	NA	NA	-0.82	NA	-0.22
Mixed Organics	NA	NA	NA	-0.09	-0.09
Mixed MSW (as disposed)	NA	NA	NA	NA	-0.10

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Values for landfilling reflect projected national average methane recovery in year 2000.

<sup>2</sup> Values are for mass burn facilities with national average rate of ferrous recovery.

**Exhibit 8-14**  
**Net GHG Emissions of MSW Management Options Compared to Landfilling<sup>1</sup>**  
**(MTCO<sub>2</sub>E/Ton)**

Negative values indicate emission reductions.

Material	Source Reduction Net Emissions		Recycling Net Emissions	Composting Net Emissions	Combustion <sup>2</sup> Net Emissions
	Minus Landfilling Net Emissions		Minus Landfilling Net Emissions	Minus Landfilling Net Emissions	Minus Landfilling Net Emissions
	Current Mix of Inputs	100% Virgin Inputs			
Aluminum Cans	-9.18	-17.15	-15.11	NA	0.02
Steel Cans	-2.92	-3.72	-1.83	NA	-1.57
Glass	-0.54	-0.61	-0.32	NA	0.01
HDPE	-1.82	-1.99	-1.44	NA	0.81
LDPE	-2.29	-2.38	-1.75	NA	0.81
PET	-1.82	-2.18	-1.59	NA	1.00
Corrugated Cardboard	-2.17	-3.79	-2.88	NA	-0.96
Magazines/Third-class Mail	-3.36	-3.94	-2.26	NA	-0.05
Newspaper	-2.21	-4.07	-2.72	NA	-0.01
Office Paper	-5.23	-5.99	-4.77	NA	-2.94
Phonebooks	-3.94	-4.37	-2.57	NA	-0.01
Textbooks	-6.78	-7.13	-5.03	NA	-2.94
Dimensional Lumber	-1.63	-1.63	-2.07	NA	-0.43
Medium-density Fiberboard	-1.82	-1.82	-2.09	NA	-0.43
Food Discards	NA	NA	NA	-0.82	-0.81
Yard Trimmings	NA	NA	NA	0.15	0.11
Mixed Paper					
Broad Definition	NA	NA	-2.84	NA	-1.06
Residential Definition	NA	NA	-2.72	NA	-0.93
Office Paper Definition	NA	NA	-3.62	NA	-1.18
Mixed Plastics	NA	NA		NA	0.90
Mixed Recyclables	NA	NA	-2.99	NA	-0.80
Mixed Organics	NA	NA	NA	-0.32	-0.33
Mixed MSW (as disposed)	NA	NA	NA	NA	-0.38

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

<sup>1</sup> Values for landfilling reflect projected national average methane recovery in year 2000.

<sup>2</sup> Values are for mass burn facilities with national average rate of ferrous recovery.